(19) Eur päis hes Patentamt
Eur pean Patent Offic
Office européen des brevets

(11) Publication number: 0 257 148 A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 86306356.6

(22) Date of filing: 18.08.86

(51) Int. Cl.4: B29D 31/00 , B29D 24/00 , B64C 3/18

(43) Date of publication of application: 02.03.88 Bulletin 88/09

(84) Designated Contracting States: BE CH DE LI SE

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(54) Improvements relating to the joining of aircraft skin panels of the sandwich type to frame elements.

(57) A joint 22 between a sandwich skin panel 20 and an elongate structural frame element 16 of an aircraft is formed using a woven fabric connector strap of substantially H shaped cross-section formed by intersecting woven fabric webs 38,40,42 in which each of the webs comprises a plurality of multifilament yarn strands F extending side-by-side transversely to the longitudinal direction of the strap and passing directly through the intersecting web or webs, the crossing web 38 having portions 44F and 44R projecting transversely from opposite sides of the two spaced upright webs 40,42 of the connector H. A groove 56 is cut through the inner face-sheet 32 and core 36 of the skin panel 20 leaving the outer face-sheet 34 intact, and the connector H is fitted into the groove with the lower portions 40L,42L of the spaced webs overlying and adhesively bonded to the exposed edges of the core 36 along the side walls of the groove, and the transversely projecting portions 44F,44R of the crossing web 38 overlying and adhesively bonded to the inner face-sheet 32 on opposite sides of the groove whereby the yarn strands F of the crossing web 38 bridge the groov 56 and restore the continuity of the inner face-sheet. A foam insert 54 fills the void in the groove 56 between the web portions 40L,42L bonded therein. The frame element 16 is received between the upper portions 40U,42U of the upright connector webs on the other side of the crossing web 38 from the groove, and these upper web portions 40U,42U are adh siv ly bonded to the opposite faces 26,28 of the frame element thereby completing a double shear bond between the frame element and the skin pan l.

EP 0 257 148 A1

IMPROVEMENTS RELATING TO THE JOINING OF AIRCRAFT SKIN PANELS OF THE SANDWICH TYPE TO FRAME ELEMENTS

Some of the aircraft built in recent years have done away with metal-skinned wings, tail assemblies, engine housings and fuselages in favour of equally-strong but lighter weight fibre-reinforced composite skin panels. Where the structure is subject to bending stresses and the like, especially during flight manoeuvers, these skin panels are traditionally constructed of lightweight rigid core materials overlayed on both faces by sheets which may have any one of a number of different forms. For example, the sheets may be in the form of "mats" which are made of randomly-oriented chopped filaments or swirled filaments with a binder bonding them together. In another form the sheets may be fabricated from so-called "endless" filaments which are bundled together and twisted to form strands of yarn which are then woven, laminated together and otherwise manipulated and adhesively-bonded into sheets. The resulting "sandwich" panel becomes, therefore, the basic covering material of the structure.

Sandwich constructions of the type just described exhibit the properties of a beam with the core corresponding to the web while the face-sheets function in the manner of the flanges. The face-sheets carry the axial tensile and compressive loads, whereas the core sustains the shear and compressive stresses normal to the skin and thus prevents wrinkling or buckling under axial compressive loads. Specifically, with reference to an aircraft wing having spars fixed between upper and lower skin panels of the sandwich type extending spanwise thereof, these elements together with the usual ribs co-operating with one another to define the aerofoil shaped wing, in the resulting so-called "monocoque" sandwich structure, the axial forces of tension and compression brought about by bending moment loads are carried entirely by the face-sheets in the upper and lower skins, and the resulting shearing forces are transferred totally in the webs of the spars.

In the past, when attaching a shear web to a sandwich skin panel, two procedures have been most often followed. The first of these is to bring the inner and outer face-sheets together along the line where the spar is to be attached by eliminating the core in this area, then mechanically joining the sides of the spar to the face-sheets thus stacked using rivets or other fasteners penetrating the stack together with overlying flanges of a pair of L-shaped connectors attached to both sides of the spar and running spanwise therealong to complete the joint. While this method is both fast and simple, it produces a structure that sacrifices a significant proportion of its resistance to chordwise bending.

The second method is similar to the first in many respects except that a span-wise strip of resin having a higher density than the rest of the core is integrated into the skin panel underlying both the spar and the outstretched legs of the L-shaped connectors adhesively attached to the inner face-sheet. This method is somewhat simpler in that it does not require cutting a channel through the core and then filling it up again with a higher density core. Also, by forming the spar-to-face-sheet connection as just described, the continuity of the core across the joint is retained along with its ability to transfer shear. Probably the only real shortcomings of this method are its inherent increase in weight and the fact that it becomes much more labour-intensive.

Fabric straps or bands folded lengthwise into an L-shape and bonded or otherwise adhered to adjoining surfaces of the skin panels and spars or other frame elements where they meet to d fin a sharply-angled corner offer a solution to the skin penetration problem, and such joints are widely used although they have somewhat more of a tendancy to pull away from the corners if overstressed than a joint where the web of the fabric is not folded at an inside corner. As in the case f the face-sheets of the skin panels, the straps or bands may be woven from multifilament yarn strands.

It is also known to weave fabric straps or bands having a three-dimensional section formed by intersecting webs of the strap. An example of such a strap and its use in a joint between an aircraft sandwich skin panel and a spar is described in U.S. Patent No. 4395450. This document discloses a resin impregnated woven fabric strap or band having a substantially H-shaped cross-section in which the central crossing web is interwoven with the two spaced webs to intersect these webs and project laterally on opposite sides thereof. Reinforcing cores are fixed between the two spaced webs on both sides of the central web, and further reinforcing cores are fixed outside the spaced webs on one side of the central web. The structure effectively forms a T-shaped connector, and is fitted in a groove cut through the inner face-sheet and the core of a skin panel so that the ends of the bar portion of the T-connector abut the edges of the skin panel core along the sides of the groove, and the leg portion of the T-connector projects to

abut the longitudinal edge of the spar. The inner surfaces of the skin panel, the T-connector and the spar are then covered with a reinforcing cover sheet.

While the joints produced by these and other prior art methods for joining frame elements to fibre-reinforced composite skin panels have proven generally satisfactory and, for this reason, are in widespread use, we have found that they can be improved upon by a simpler and more effective use of a three dimensional woven fibre strap or band of generally H-shaped cross-section in a way that takes maximum advantage of the inherent superior ability of yarn strands made up of bundles of endless filaments to carry large tension loads.

According to one aspect of the invention, there is provided a joint between a sandwich skin panel of an aircraft or aircraft component and an elongate structural frame element, wherein the skin panel comprises a core bounded on opposite faces by inner and outer face-sheets, the joint comprising a groove cut through the inner face-sheet and the core of the skin panel leaving the outer face-sheet intact, a woven fabric connector strap extending longitudinally along the groove and formed by a pair of substantially parallel spaced woven fabric webs intersected by a further woven fabric web to provide the strap with a substantially H-shaped cross-section in which the further web forms the cross-bar of the H-section and has portions projecting transversely from opposite sides of the two spaced webs, each of the webs comprising a plurality of multifilament yarn strands extending side-by-side transversely to the longitudinal direction of the strap and passing directly through the intersecting web or webs, the portions of the two spaced webs of the connector strap on one side of the crossing web being received in the groove and adhesively bonded to the exposed edges of the core along the side walls of the groove, and the transversely projecting portions of the crossing web overlying and being adhesively bonded to the inner face-sheet on opposite sides of the groove whereby the crossing web bridges the groove and restores the continuity of the inner face-sheet, a structural insert filling the void in the groove between the portions of the webs within the groove, and the frame element having a longitudinally extending edge received between the portions of the two spaced webs on the other side of the crossing web from the groove, said web portions overlying and being adhesively bonded to the opposite faces of the fram element whereby the two spaced webs form continuous load paths between the frame element and th inner and outer face-sheets.

As mentioned, the crossbar portion of the connector strap bridges the gap which is produced in the inner face-sheet of the skin panel when the groove is cut along the line on which the spar or other frame element is to be fastened, and the transversely extending "fill" strands of this crossbar portion, when adhesively-bonded to the inner face-sheet adjacent the groove edges, re-establish its continuity across the joint. Both upright portions of the connector strap do likewise by establishing an adhesively-bonded woven fabric bridge interconnecting the edges of the core exposed at the sides of the groove in the skin panel and the more or less aligned faces of the spar positioned on the other side of the crossbar portion. Any chordwise bending load tending to widen the gap in the inner face-sheet is resisted by the fill strands in the crossbar portion of the H-connector which bridge the gap and which are placed in tension. In the same way, any load tending to pull the spar out of the channel formed by the medial section of the crossbar portion and the limbs of the upright portions bonded to its sides is resisted by the entire upright portions of the H-connector as their corresponding fill strands are placed in tension. Thus, before the sharply-angled portions of the H-shaped strap or band connector defined by the juncture between the crossbar and upright portions can pull loose at the correspondingly-shaped corner defin d between the spar and skin panel, the tensioned fill strands bridging the gap or those extending vertically alongside the latter must give way by breaking, stretching or fracturing the adhesive shear bond since no strand in the connector goes around this corner, just straight through the intersection.

As has already been done to some limited degree, all of the yarn strands made up of bundles of individual filaments which extend transversely of the length of the woven strap connector, regardless of whether they form parts of the crossbar portion or upright portions of the "H" will, for the purposes of the present description, be referred to as the "fill" strands in accordance with conventional weaving and composite materials terminology. In a similar manner, those yarn strands extending longitudinally of the connector strap will, henceforth, be referred to as "warp" strands. The term "yarn" as used herein is intended to identify bundles of individual elongate filaments laid alongside on another to form a multifilament bundle comprising the basic element of the weave. Similarly, filaments and strands of yarn having a length greatly exceeding their cross-sectional area will be referred to as "endless", again in accordance with accepted composite material terminology.

The structural insert filling the channel or void between the web portions of the connector that are received in the groov and are adhesively attached to the edges of the core exposed within the groove has, as its principal function, that of backing these web portions and ensuring that they make broad area contact with the adjacent core surfaces to achieve a secure bond between them. Bridging the gap left by the groove in the core material with the insert, which is preferably of a rigid foam material, does of course restore its continuity and, at least to some extent, its ability to transfer shear loads across the gap.

The warp strands of the fabric connector are preferably interwoven among the fill strands at right angles thereto in the manner of the more common woven fabric structures. However, the fill strands of the crossbar portion, which for the purposes of the present description will be said to extend horizontally, are spread apart at spaced intervals to produce the gaps through which the vertically-extending fill strands of the upright portions of the H-connector pass, and vice versa. The warp strands are not without function in the woven connector used in accordance with the invention since they resist the compression loads experienced primarily by the inner face-sheets of wing skin panels and the tension and compression loads applied to the outer face-sheets as the wing bends about chordwise axes.

According to another aspect of the present invention, a method of fastening an elongate frame element, such as a wing spar, to an aircraft skin panel of the sandwich type having a core bounded on opposite faces by inner and outer face-sheets comprises cutting a longitudinally-extending groove through the inner face-sheet and core of the panel to expose the edges thereof while leaving the outer face-sheet intact, bridging the gap in the inner face-sheet created by the groove with a first set of multiple fibre yarn strands extending transversely thereof in side-by-side relation and overlying the inner face-sheet adjacent the groove, adhesively-bonding said first set of yarn strands to said inner face-sheet to re-establish the continuity of the latter, intersecting the first set of yarn strands with a second set of multiple fibre yarn strands and adhesively-bonding said second set of yarn strands to a face of the frame element located outside the groove and to an exposed edge of the skin panel core within said groove to establish a continuous load path between said frame element and said inner and outer face-sheets, filling the void in the groove bounded by the edges of the core, the outer face-sheet and the overlying first set of yarn strands with a structural insert, interweaving a third set of multiple fibre yarn strands with the yarn strands of the first and second sets thereof both inside and along both sides of the groove and alongside the frame element, and adhesively-bonding said third set of yarn strands to the underlying surfaces of the inner face-sheet, the core, and the frame element so as to resist the axial tensile and compressive forces to which the skin panels are subjected as the assembly bends.

As will be appreciated, the sets of multiple fibre yarn strands are preferably incorporated in a woven H-shaped connector strap as described earlier.

The invention thus provides for connecting frame members of one type or another to sandwich skin panels in a manner which is simple, fast, versatile, easy to carry out, devoid of metal fasteners, and leaves the outer face-sheet intact and without puncture holes. It provides a low-weight assembly with superior strength when compared with prior art methods employed for the same purpose, and makes full advantage of the ability to weave the connector in virtually unlimited lengths for accommodating long spar-to-skin joints and the like.

Examples of the joint and method in accordance with the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a fragmentary perspective view, partly in section, showing a portion of an aircraft wing which includes spanwise spars and skin panels, all of sandwich construction, joined together by H-shaped woven fabric connectors to form joints in accordance with the invention;

Figure 2 is a fragmentary perspective view, partly in section and much like Figure 1 but to a greatly enlarged scale, showing the elements of the joint assembly preparatory to being moved into final position and bonded together;

Figure 3 is a fragmentary perspectiv view like Figure 2 and to the same scale showing the completed joint;

Figure 4 is a fragmentary perspective view like the preceding figures and to approximately the same scale as Figures 2 and 3 showing the woven fibre H-shaped connector used to joint the spars to the skin panels before it is laid up in the forming tool and treated to rigidify same;

Figure 5 is a still further enlarged fragmentary perspective view showing a portion of the woven connector with particular emphasis upon the weave of the yarn strands, both fill and warp, that make it up;

Figure 6 is a fragmentary plan view to a much smaller scale than Figure 5 revealing the weave pattern in which the fill strands are interwoven among the warp strands;

Figure 7 is a diagram showing the manner in which the woven multifilament strap connector is impregnated with resin before being rolled and dried;

Figure 8 is a diagram similar to Figure 7 showing how the connector thus impregnated is laid up in a segmented forming tool which holds it in the desired shape while it is being autoclaved or otherwise treated to cure and harden same;

Figure 9 is a fragmentary perspective view much like Figure 4 but to a slightly larger scale showing the cured and rigidified connector with the foam insert in place therein;

Figure 10 is a diagram illustrating the manner in which a section of an aircraft wing responds to bending loads; and

Figure 11 is a fragmentary perspective view very much like Figure 3 except that it shows some of the major forces acting on the joint and the inner and outer face-sheets of the lower sandwich skin panel it attaches to the spar web.

Referring now to the drawings in detail, Figure 1 shows a section of an aircraft wing in the form of a box beam indicated in a generaly way by reference numeral 10 which is made up of fore and aft spars given numerals 12 and 14, respectively; a centre spar 16; upper and lower skin panels 18 and 20, respectively; one type of joint indicated broadly by reference numeral 22 shown connecting the upper and lower edges of the fore and centre spars to the upper and lower skin panels; and quite a different joint 24 connecting the aft spar 14 to the rear skin panel edges. In the enlarged fragmentary detail of Figures 2 and 3 where the joint 22L formed between the lower edge of the centre spar 16 is made with the lower skin panel 20, both the spar and panel can be seen as sandwich structures wherein a pair of face-sheets are adhesively-bonded to opposite faces of a rigid core material. The fore and aft face-sheets 26 and 28, respectively, together with the core 30 therebetween when bonded together produce the spar web which is a special type of frame element, the function of which is to transfer shear as well as to hold the skin panels above and below the latter in precise fixed spaced relation to one another while co-operating with the ribs (not shown) to produce an aerofoil. In a similar manner, the inner and outer face-sheets 32 and 34, respectively, of the lower skin panel 20 are adhesively-bonded top and bottom to a suitable core 36. The centre joints 22 are constructed in accordance with the invention using wov n fabric H-connectors that are indicated broadly in th drawings by the ref renc letter H.

Before proceeding with a description of the joint 22 and the method of constructing same, it is important that one understands the construction of the woven web connector H, for which purpose reference will next be made to Figures 4 and 5. In Figure 4 it will be seen that the connector is generally H-shaped in cross-section having a crossbar portion 38 intersected intermediate its side margins by a pair of transversely-spaced substantially parallel upright portions 40 and 42. The crossbar portion 38 has flanges 44F and 44R projecting fore and aft of the upright portions 40 and 42 as shown. In addition, the crossbar portion includes a medial web-forming section 44C located between the upright portions that co-operates with two of their limbs 40L and 42L on the same side thereof to define a foam-receiving channel 46. In like manner, this same medial section 44C of the crossbar portion co-operates with the remaining two limbs 40U and 42U of the uprights to define a second web-receiving channel 48.

Directing the attention next to Figure 5, it will be noted that the connector H is fabricated from multifilament strands of yarn Y interwoven to produce the H-shaped cross-section previously described. Each strand of yarn is made up of a plurality of individual hair-like fibres which may be glass, graphite, a material sold under the trademark "Kevlar" or whatever other substance one wishes to use having the properties required in the finished joint. In Figures 5 and 6, the warp strands carry the designation W while those of the fill are identified with the letter F. The white arrows trace the course of a single fill strand making up the crossbar portion 38 of the connector H and particularly the aft flange 44R of the latter. Several significant features should be noted, perhaps the most important of which is the fact that each fore and aft run thereof does not go up or down but rather extends right through the intersection formed by the strands of the upright portions 40 and 42 indicated by the black arrows and which are pushed aside to create a gap most clearly seen at 50 accommodating same. In like manner, the adjacent fill strands of the crossbar portion identified by the white arrows are parted to create a gap through which the strands of the aforementioned upright portions 40 and 42 identified by the black arrows pass. The warp strands W, on the other hand, weave over and under adjacent strands of the crossbar portion as well as in front of and behind the adjacent strands of the upright portions.

Referring next to Figures 5 and 6, it will be seen that the adjacent runs or lays of the fill strands F in both the crossbar portion and the upright portions of the connector lie in side-by-side parallel ssentially contacting relation xc pt at the intersections wher they must be part d to create th gaps necessary for intersecting fill strands to pass through, all of which can be most easily followed by tracing the paths of the black and white arrows. In the particular form illustrated in Figures 5

and 6, all the fill strands are continuous in that they are laid back and forth reversing direction at each end to produce a finished edge identified by the numeral 52 where one of the crossbar strands is shown passing over the top of the outermost warp strand on the near edge before reversing direction and passing back underneath the latter. This same finished edge is found on the front of the crossbar portion and along both the top and bottom edges of the upright portions. The warp strands W, on the other hand, are not continuous, but rather, terminate at the remote ends of the tape as can best be seen in Figure 6. It is worthy of mention, however, that this continuous strand construction found in the fill strands, while most desirable and by far the most practical from a weaving standpoint, is not critical from the perspective of the joint to be formed since each lay or run of all the strands, both fill and warp, are ultimately bonded to a face-sheet, a side of the spar or the skin panel core exposed at the sides of the groove 56 routed in the skin panels that is revealed most clearly in Figure 2. When thus bonded to an appropriate support structure, the fact that the strands terminate or, alternatively, wrap around a warp strand really has little if any structural significance.

(Before the woven fibre connector H can be laid up in the wing, it is preferably first passed through a bath as indicated schematically in Figure 7 where it is impregnated with a suitable heat-curable resin.) With the tape connector thus impregnated it is held and formed into the shape it will occupy in the finished assembly by means of a multi-segment forming tool 58 that has been illustrated somewhat schematically in Figure 8. In general, the tool itself is designed to both hold and press against the flanges 44F and 44R of the crossbar portion 38 both top and bottom as well as the limbs 40U and 42U of the upright portions both fore and aft so as to maintain the filaments thereof in compacted relation to one another while they are being cured. The medial section 44C of the crossbar portion 38 is supported by the tool only from above. The same is true of the limbs 40L and 42L of the upright portions which are backed-up by the tool only on the outside. This, of course, leaves the channel 46 defined by the medial section of the crossbar portion and the limbs 40L and 42L of the upright portions free to accept the structural foam insert 54 which is inserted at this time thus providing both the missing support for the underside of the medial section 44C and the inside surfaces of the aforementioned limbs but, in addition, the pressure required to compact the filaments thereof so that they will cure properly. The tool with the connector spread out and its flanges thus compacted is then placed in a h at-resistant bag or env lope 60 and autoclaved or otherwise treated to cure same. When the tool is disassembled, the connector H will be cured and in the precise shape required for the final ass mbly into the wing or other component.

Referring briefly again to Figure 4, in th particular form in which the connector has been shown therein, it will be seen that the limbs 40U and 42U of the upright portions have their free edges 60U and 62U flared fore and aft slightly. The purpose of this is so that they will more easily receive th spar web 16 in the manner shown in Figures 2 and 3.

Following the autoclaving or other curing operation, the connector H will be as shown in Figure 9 and already contain the structural foam filler 54. In Figure 2, the lower skin panel 20 has been shown grooved and ready to receive the foam-filled channel 46 of the connector. Groove 56 is routed spanwise of the wing, both top and bottom, to receive the aforementioned foam-filled rigidified the rigidified connector located either above or below the crossbar portion 38. Once the outer surfaces of the limbs 40L and 42L of the upright portions of the connector are adhesively-bonded to the core of the skin panel sandwich exposed within the groove 56 and the bottom of the foam insert is similarly bonded to the exposed inner surface of the outer face-sheet 34 which is left intact, the gap produced by the groove 56 is filled although the foam filler has little, if anything to do with restoring the face-sheet's lost resistance to bending, the latter having been provided to some extent at least by the connector itself. This same groove has cut through the inner face-sheet 32 and thus destroyed its continuity. When, however, the fore and aft flanges 44F and 44R of the connector are bonded to face-sheet 32 on opposite sides of the groove, this continuity is restored and, most significantly, the strands of the connector bridging the gap formed by the groove extend straight across the latter so that they can be loaded in either tension or compression. With the limbs 40U and 42U of the upright portions of the connector properly bonded to the sides of the spar web 16 in the manner shown in Figure 3, a continuous load path between the latter and both the inner and outer face-sheets of the skin panel is established. Note also in connection with Figure 3 that the spar web is not shown seated all the way to the bottom of spar-receiving channel 48 of the connector. These flanges 40U and 42U of the uprights, therefore, allow for considerable tolerance in the connections between the spars and skin.

Turning attention next to Figure 20, it can be s en that when the wing bends, the upper skin panel is in compression while the lower skin panel is in tension. The bending moment is represented by the equation:

$(M) = P \times L$

where M is the bending moment, P is the bending force and L is the length of the moment arm, in this case the wing. The shearing force (q) in the above diagram resists the relative slipping motion of the upper and lower skin panels caused by the upper skin panel trying to contract and grow shorter due to compression while the lower skin panel extends and stretches due to the tension in the system. In a sandwich structure like those shown here, the axial forces of tension and compression that result from the bending forces exerted on the wing are carried by the inner and outer face-sheets in the skin panels. More significant, however, for purposes of the present invention is the fact that the resultant shearing forces are transferred totally in the webs of the spars where the connector provides a continuous load path between the spar web and both the inner and outer face-sheets.

Finally, with particular reference to Figure 11, it can be seen that the H-connector provides a structural joint joining the spar to both the inner and outer face-sheets of the sandwich skin panels, both upper and lower. In so doing, the skin panels are, for all practical purposes, left continuous and undisturbed. The grooves in the skin panels are replaced with the portions of the H-shaped connector bonded to the exposed edges thereof along with the foam filling the space between the two, the latter functioning to restore the continuous shear joint while, at the same time, backing up these portions of the connector thus insuring that they make the broad area contact with the skin panel core required for a reliable adhesively-bonded connection. The gaps left in the inner face-sheets are bridged by the crossbar portion of the H-connector extending thereacross and bonded to the face-sheet surfaces adjacent the groove.

In a similar manner, the upright portions of the H-connector provide a continuous load path between the spar webs and both the inner and outer face-sheets. As indicated by the arrows in Figures 1 and 11, the face-sheets of the skin panels carry the axial tensile and compressive stresses while the core sustains the shear and compressive stresses normal to the skin and thus prevent the skin from wrinkling or buckling under axially-directed compressive loads.

Accordingly, a wing constructed in accordance with the above-described method using a woven H-shaped connector results in an efficient connection because, among other features, it utilizes a redundant double shear bond joint with the spar web. Also, assembly is simple and fast because the spar web need only be slipped into the opposed channels of the H-connectors sitting atop the grooves. Moreover, since these web-receiving channels are quite deep, it is not necessary that the spar web seat all the way to the bottom and this, of course, provides ample assembly tolerances.

Finally, while the method forming the subject matter hereof has been described in detail in connection with the wings and spars of a sandwich panelled aircraft, shear, tensile and compressive forces are also at work in other portions of the assembly like, for instance: canard, the elem nts of the tail subassembly and even the longitudinal stringers that form parts of the frame structure supporting the walls of the fuselage. For this reason, the assembly techniques used in the spar-to-wing connection are equally applicable to other sandwich panel-to-frame connections and the claims which follow have been so worded.

Claims

1. A method of joining an elongate frame element (16) to an aircraft skin panel (18,20) of the sandwich type comprising a core (36) bounded on opposite sides by inner and outer face-sheets (32 and 34), wherein a longitudinally extending groove (56) is cut through the inner face-sheet(32) and the core (36) of the panel to expose the edges thereof while leaving the outer face sheet (34) intact, characterised by bridging the gap in the inner face sheet (32) created by the groove (56) with a first set of multiple fibre yarn strands (38F) extending transversely thereof in side-by-side relation and overlying the inner face-sheet (32) adjacent the groove (56), adhesively bonding said first set of yarn strands (38F) to said inner face-sheet (32) to re-establish the continuity of the latter, intersecting the first set of yarn strands (38F) with a second set of multiple fibre yarn strands (40F) and adh siv ly bonding said second set of yarn strands (40F) to a face (26) of the frame element (16) located outsid the groove (56) and to an exposed edge of th skin panel core (36) within said groove (56) to stablish a continuous load path between said frame el ment (16) and said inner and outer face-sheets (32 and 34), filling the void in the groove (56) bounded by the edges of the core (36), the outer face-sheet (34), and the overlying first set of yarn strands (38F) with a structural insert (54), interweaving a third set of multiple fibre yarn strands (W) with the yarn strands (F) of the first and second sets thereof both inside and along both sides of the groove (56) and along side the frame element (16), and adhesively bonding said third set of yarn strands (W) to the underlying surfaces of the inner face sheet (32), the core (36), and the frame element

(16) so as to resist the axial tensile and compressive forces to which the skin panels are subjected as the assembly bends.

2. A m thod according to claim 1, further characterised by intersecting the first set of yarn strands (38F) with a fourth set of multiple fibre yarn strands (42F) substantially parallel to the second set (40F) and spaced to one side thereof by approximately the thickness of the frame element (16), and adhesively bonding the fourth set of yarn strands (42F) to the other face (28) of the frame element (16) on one side of the first set of yarn strands and to the other exposed edge of the core (36) within the groove (56) on the other side of the first set whereby the second and fourth sets of yarn strands (40F) and (42F) form a double shear bond connection between the skin sandwich panel and the frame element, the third set of yarn strands W also being interwoven with the fourth set (42F).

3. A method according to claim 1 or claim 2, wherein the three or four sets of yarn strands (38F, 40F, 42F, W) are interlaced to produce a limp woven fabric connector (H) of cruciform cross-section prior to attachment to the frame element (16) and the panel (20), further characterised by impregnating the connector thus formed with a heat curable hardener, supporting the impregnated connector in a mould (58) shaped to hold the connector (H) in the form in which it is to be bonded to the skin sandwich panel (20) and the frame element (16), and heat curing the connector (H) while in the mould (58) to rigidify the connector.

4. A method according to claim 3, which includes leaving a longitudinally extending passage (46) in one quadrant of the intersection between the first and second sets of yarn strands (38F,40F) of a size and shape closely approximating that of the material removed from the skin sandwich panel 18 to form the groove (56) therein, and filling said passage (46) with a foam effective to produce said structural insert (54) preparatory to heat curing the connector (H).

5. A method according to any one of the preceding claims, wherein the second set or yarn strands (40F) covers the edge of the core (36) along one side of the groove (56) and at least a portion of the outer face sheet (34) at the bottom of the groove.

6. A method according to claim 2, wherein the sides of the groove (56) are lined by the portions (40L,42L) of the second and fourth sets of yarn strands projecting on the groove side of the web (38) defined by the first set of yarn strands.

7. A method according to claim 6, wherein the bottom of the groove (56) formed by the outer face-sheet (34) is lined using at least one of the portions (40L,42L) of the second and fourth sets of yarn strands lining the sides thereof so as to box in the structural insert (54).

8. A method according to claim 2, wherein the portions (40U,42U) of the second and fourth sets of yarn strands overlying the frame element (16) have their edges (60U,62U) remote from the first set (38) turned outwardly for guiding the frame element (16) into position therebetween prior to bonding said portions (40U,42U) to the frame element (16).

9. A joint (22) between a sandwich skin panel (18,20) of an aircraft or aircraft component and an elongate structural frame element (16), wherein the skin panel comprises a core (36) bounded on opposite sides by inner and outer face-sheets (32,34), and the joint comprises a groove (56) cut through the inner face-sheet (32) and the core (36) of the skin panel leaving the outer face-sheet (34) intact, a woven fabric connector strap (H) extending longitudinally along the groove (56) and formed by a pair of substantially parallel spaced woven fabric webs (40,42) intersected by a further woven fabric web (38) to provide the strap with a substantially H-shaped cross-section in which the further web (38) forms the crossbar of the (H) section and has portions (44F,44R) projecting transversely from opposite sides of the two spaced webs (40,42), the portions (40L,42L) of the two spaced webs on one side of the crossing web (38) being received in the groove (56) and retaining a structural insert (54) therebetween, characterised in that each of the webs (38,40,42) comprises a plurality of multifilament yarn strands (F) extending side-by-side transversely to the longitudinal direction of the strap (H) and passing directly through the intersecting web or webs, the portions (40L,42L) of the two spaced webs received in the groove (56) are adhesively bonded to the exposed edges of the cor (36) along the side walls of the groove (56), the transversely projecting portions (44F,44R) of the crossing web (38) overlie and are adhesively bond d to the inner face-sheet (32) on opposite sides of the groove (56) whereby the crossing web (38) bridges the groove and restores the continuity of the inner face-sheet (32), and the frame element (16) has a longitudinally extending edge received between the portions (40U,42U) of the two spaced webs on the other side of the crossing web (38) from the groove, said web portions (40U,42U) overlying and being adhesively bonded to the opposite faces (26,28) of the frame element whereby the two spaced webs (40,42) form continuous load paths between the frame element (16) and the inner and outer face-sheets (32,34).

10. A joint according to claim 9, wherein the woven fabric conn ctor strap (H) is impregnated with a heat curable resin and heat cured to render the H section strap substantially s lf-supporting.

11. A joint according to claim 9 or claim 10, wherein the structural insert (54) is formed by a foam material located between the spaced webs (40,42) before the connector (H) is fitted into the groove (56).

12. A joint according to any one of claims 9 to 11, in which the transversely extending yarn strands (F) of each web (38,40,42) are formed by a continuous multifilament yarn strand (Y) which is woven back and forth across the web.

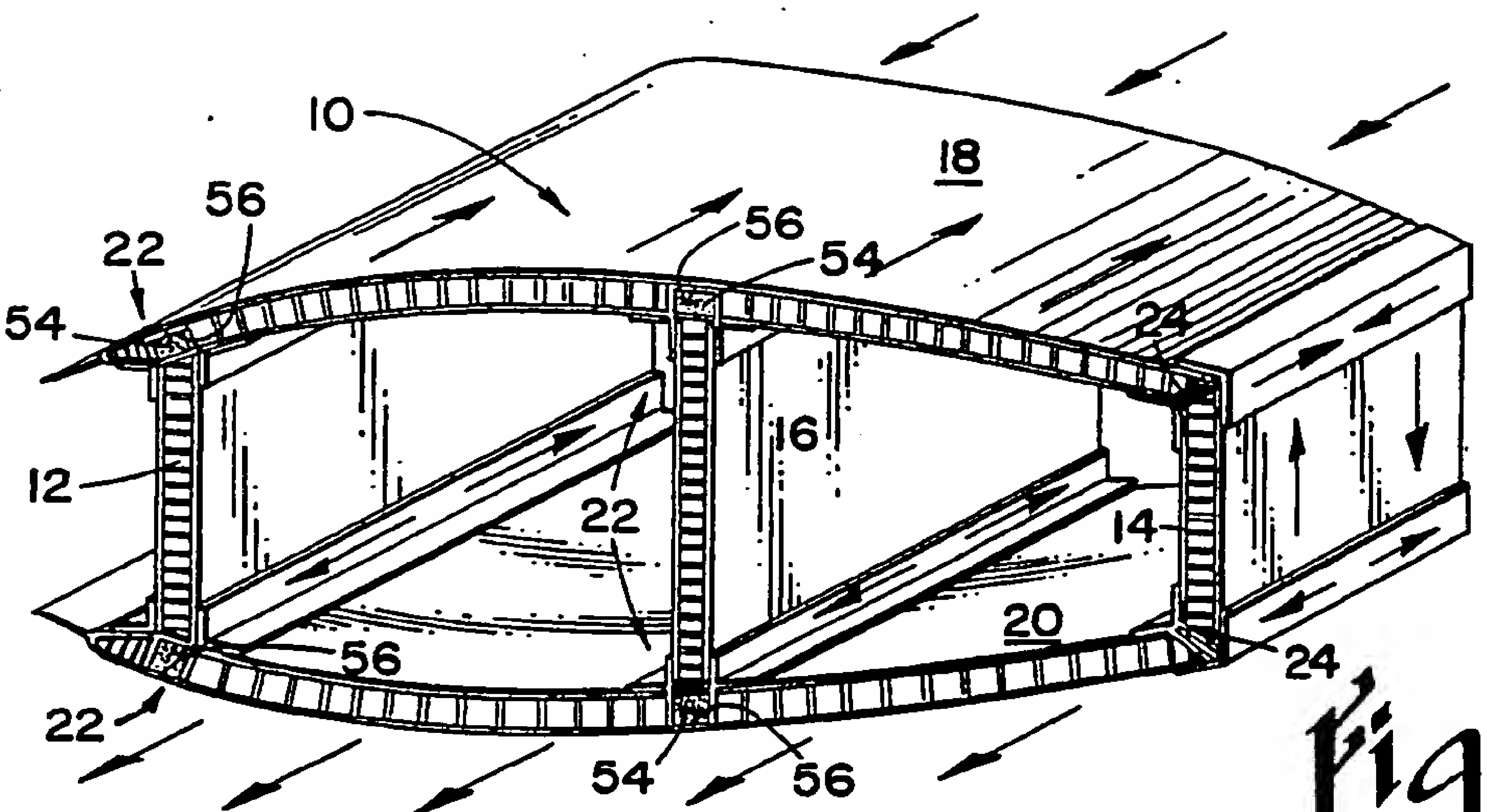

Fig. 1

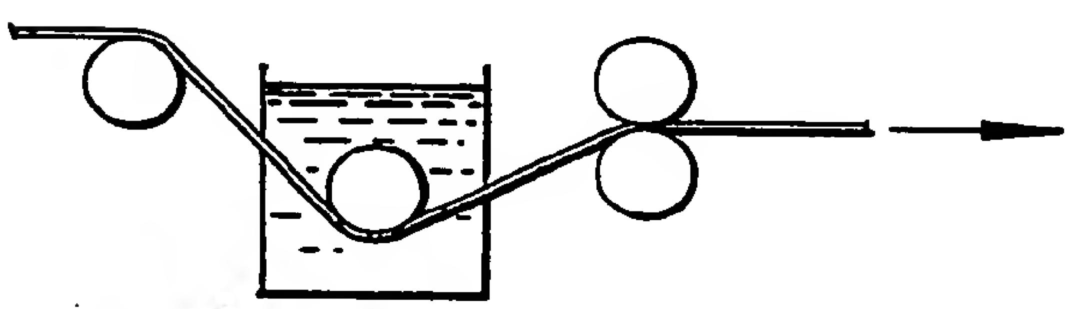

Fig. 7

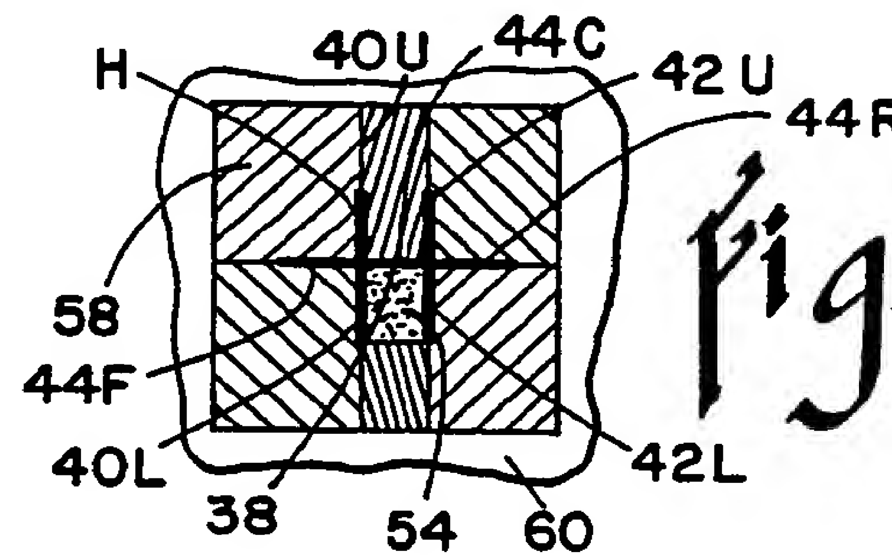

Fig. 8

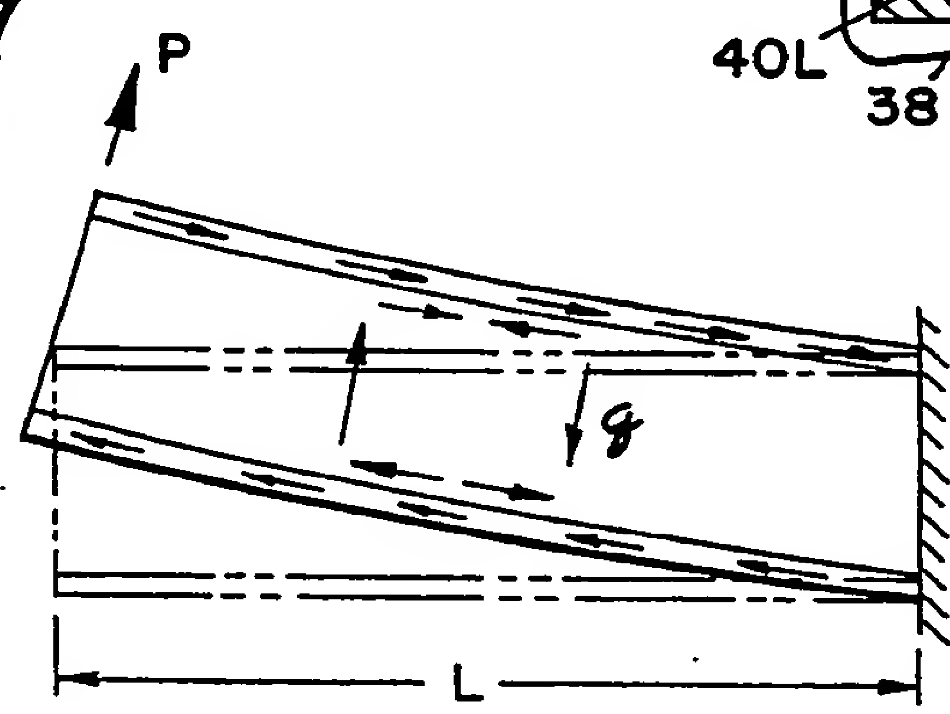

Fig. 10

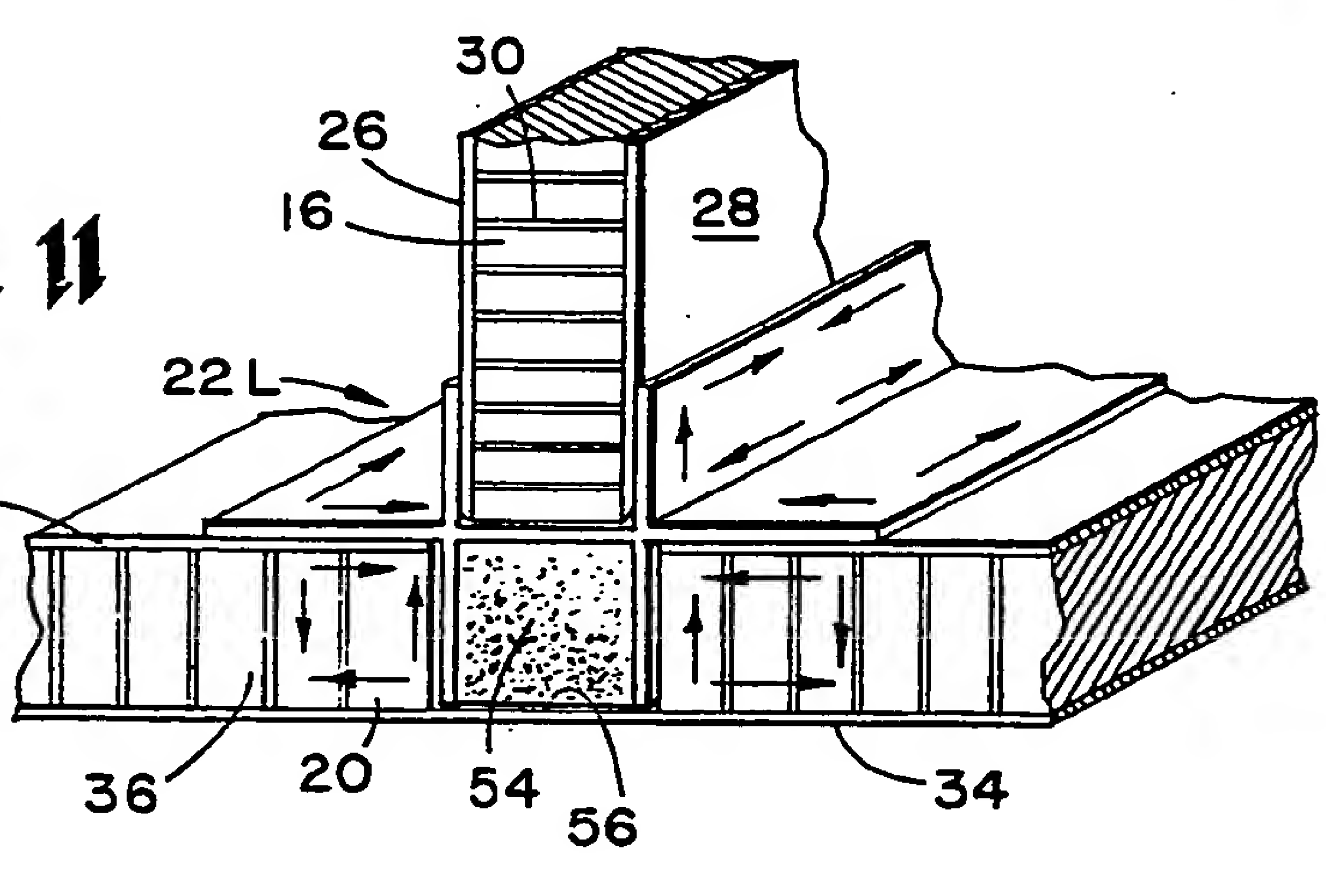

Fig. 11

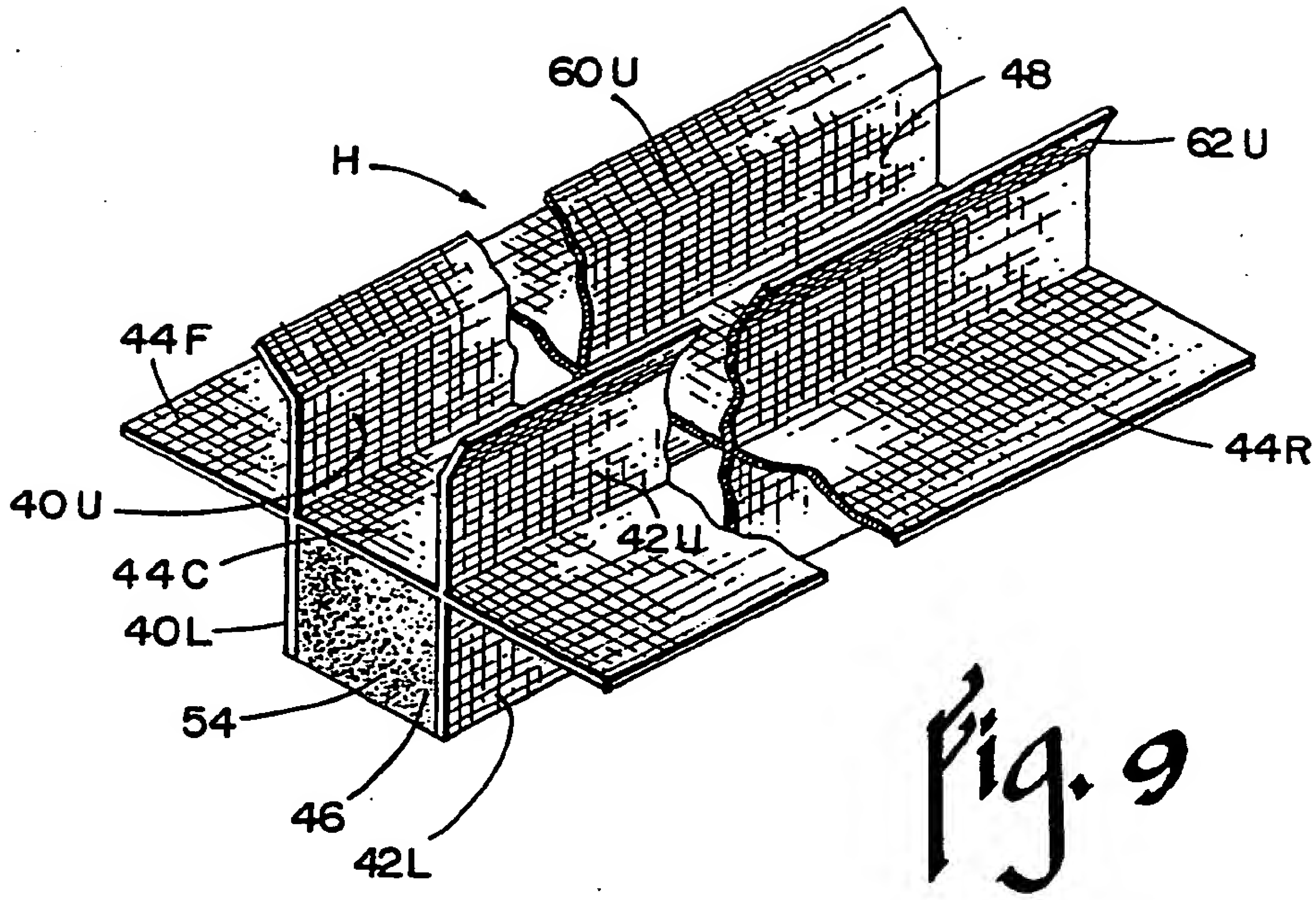

Fig. 9

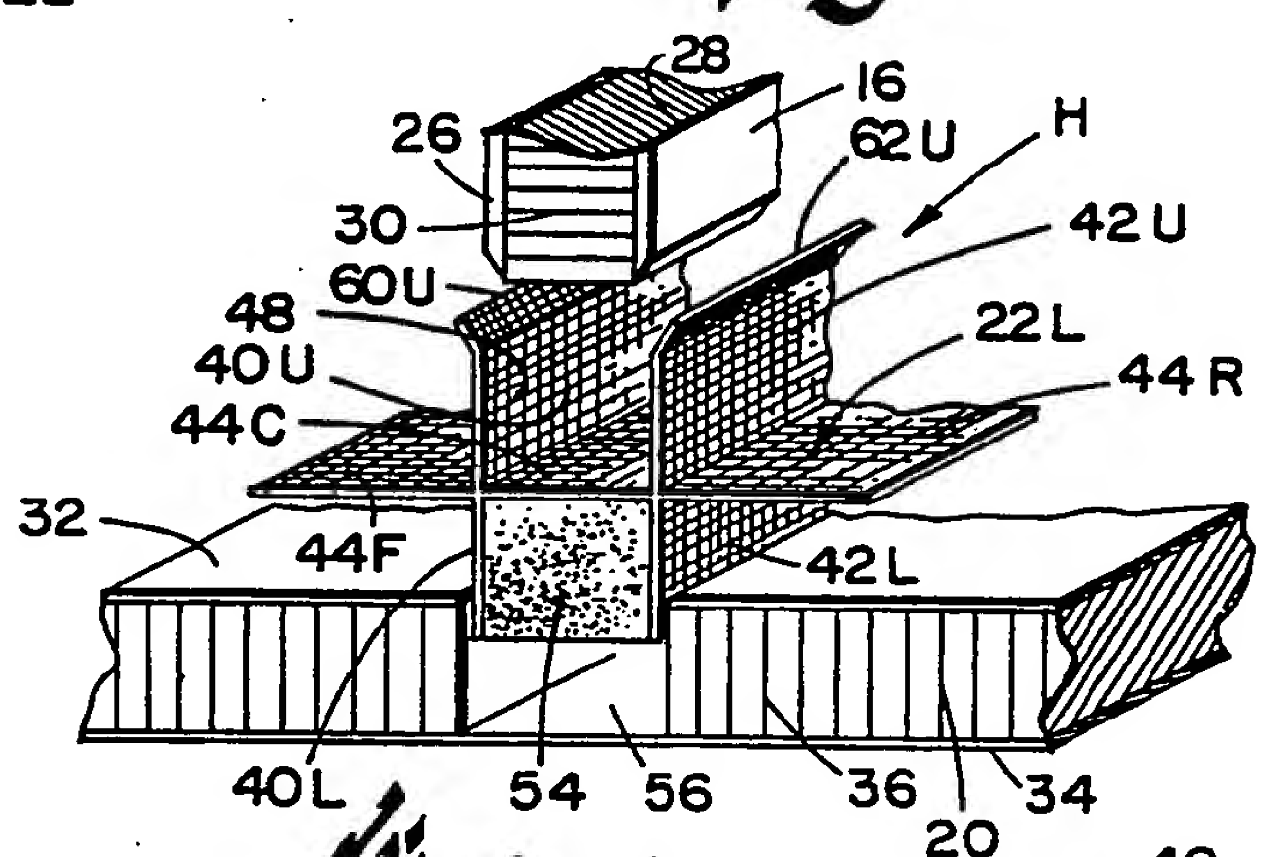

Fig. 2

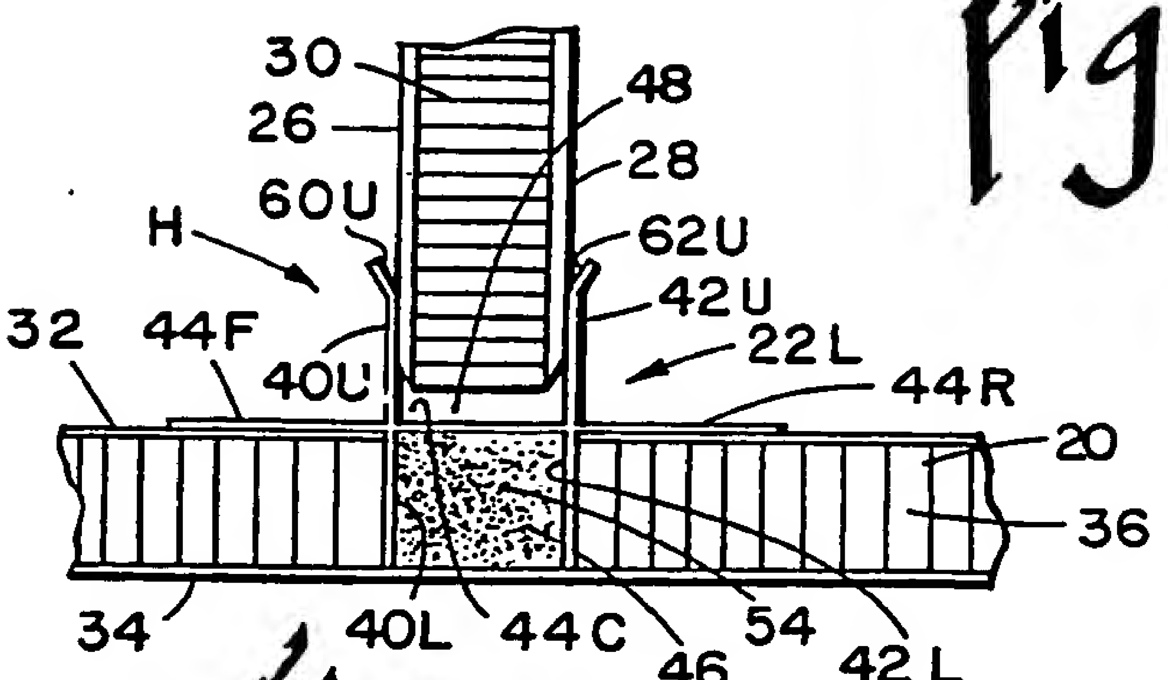

Fig. 3

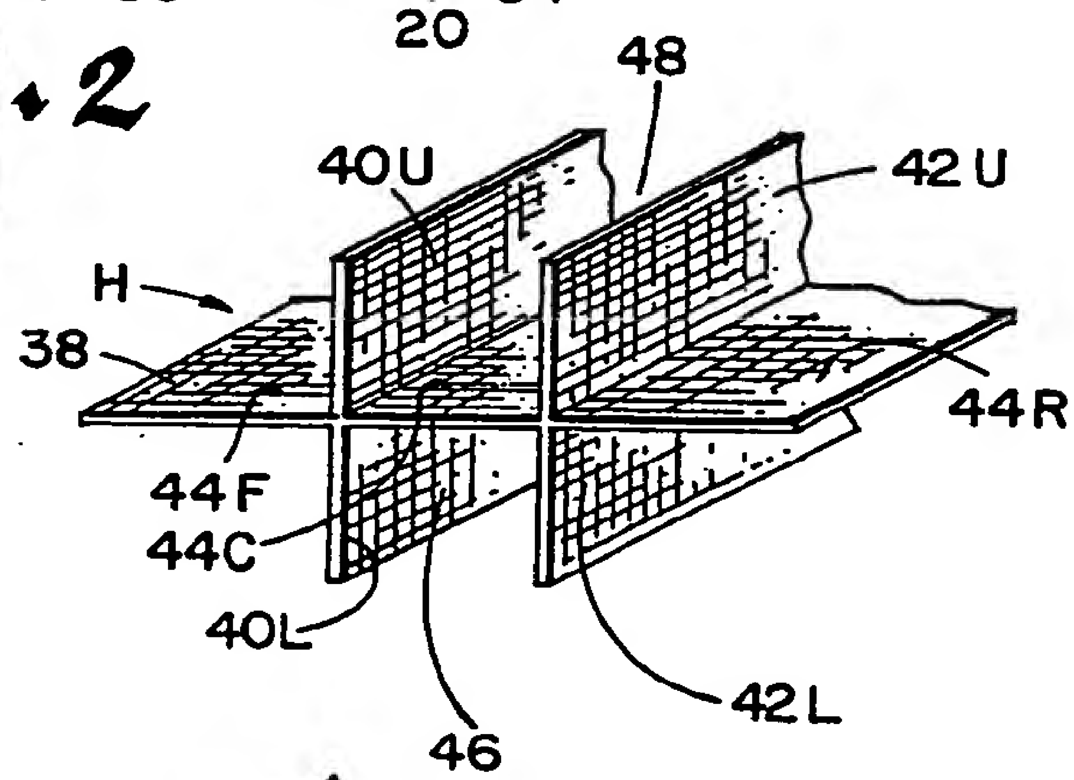

Fig. 4

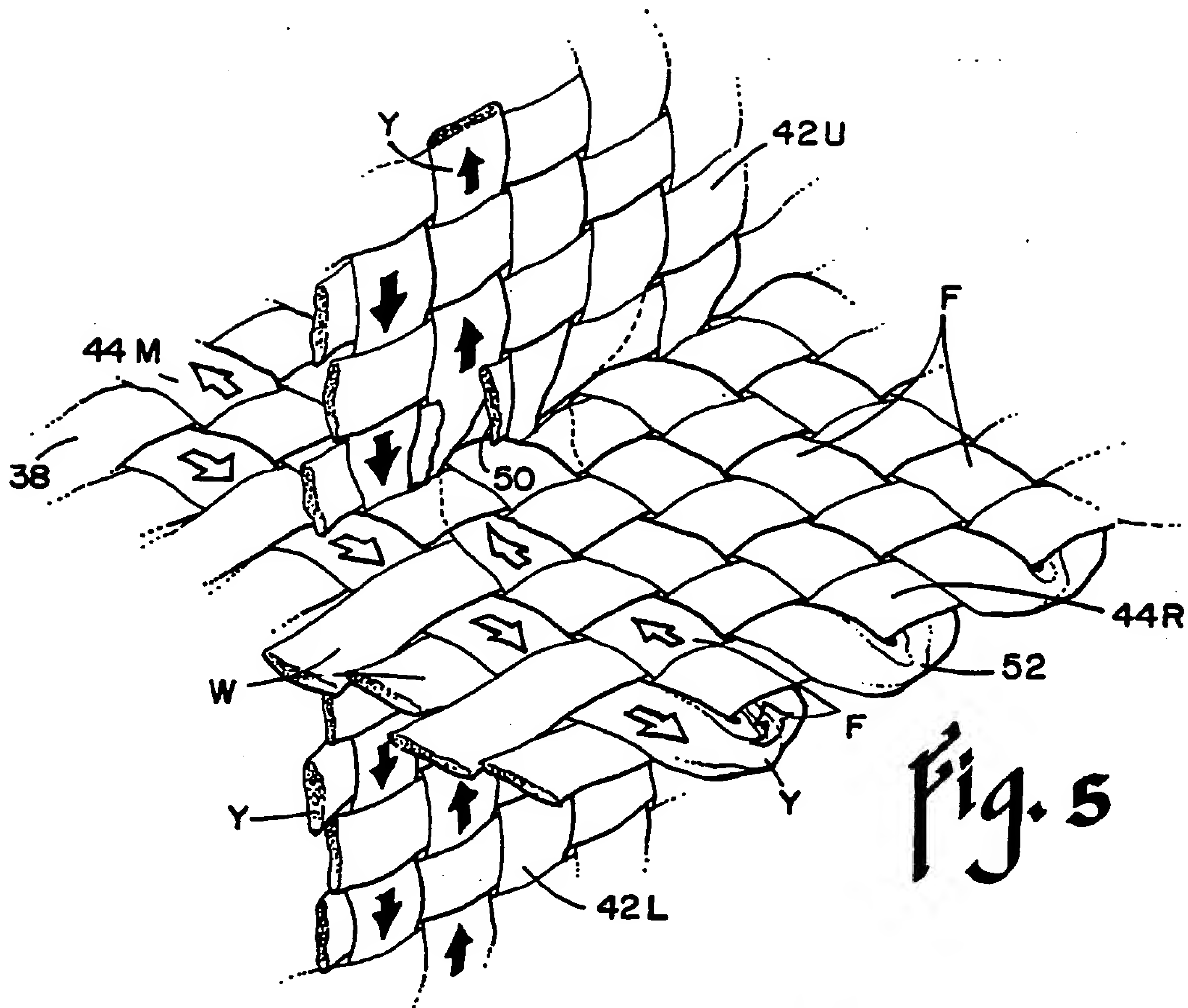

Fig. 5

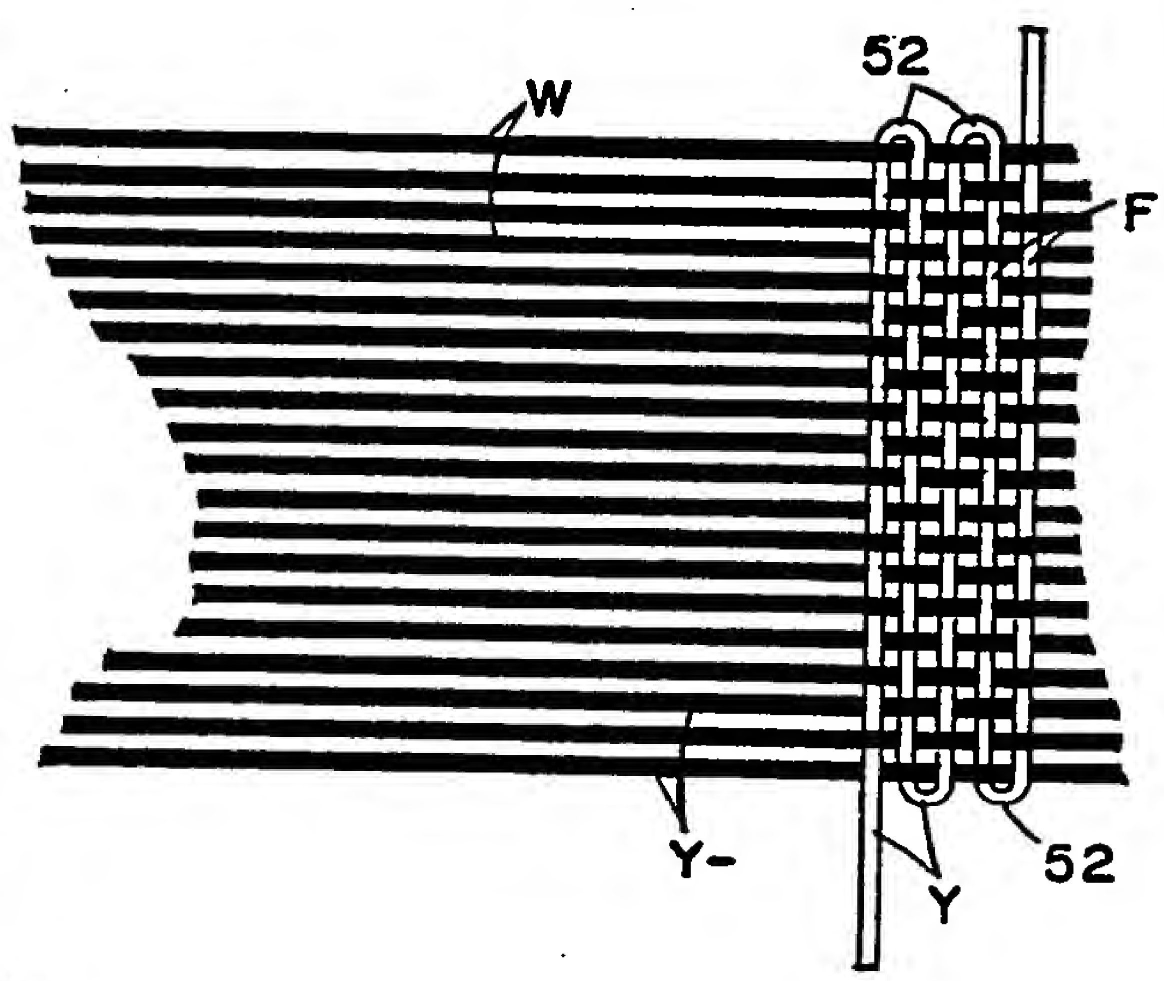

Fig. 6